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# **Comment on "Anomalous Deep Inelastic Scattering from Liquid $\text{H}_2\text{O}-\text{D}_2\text{O}$ : Evidence of Nuclear Quantum Entanglement"**

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In a recent Letter [1], C.A. Chatzidimitrou-Dreismann *et al.* report on a very interesting series of experiments of deep-inelastic scattering off H<sub>2</sub>O, D<sub>2</sub>O and H<sub>2</sub>O-D<sub>2</sub>O mixtures with different  $x_D$ , the D<sub>2</sub>O molar fraction.

While we agree with the authors that their results are in dramatic disagreement with the very reasonable expectation that the cross-section ratio  $Q = \frac{\sigma_H}{\sigma_D}$  *should be independent of*  $x_D$  (see Fig. 2 of their paper), we strongly disagree with their conclusion that Quantum Entanglement (QE) is a possible explanation of their remarkable observations. Indeed, whereas for the analogous results obtained in Raman scattering [2] QE remains a logical, though quite arduous, possibility, due to the non-local nature of the interaction of the laser field with the water molecules, for the deep inelastic scattering process analysed in Ref. [1] the high values of the momentum transfers (or, equivalently, the small values,  $< 0.1\text{\AA}$ , of the wave-lengths involved) make any spatial coherence among different nuclei essentially impossible. Let us recall that it is precisely the basic incoherence of the scattering nuclei (H, D or O) that lies at the roots of the validity of the "impulse approximation", which appears to give an adequate description of the experimental data [1].

If not QE, what else can then explain the observations of Refs. [1] and [2] ? We would like to suggest that the surprising  $x_D$ -dependencies found in the latter papers can be easily and naturally understood within a new approach to condensed matter described in a recent book [3], and applied to water in Ref. [4]. According to QED-coherence (for in this approach one takes into account the many-body coherent electrodynamic interaction among the water molecules) water consists of two interpenetrating fluids, one consisting of molecules oscillating in phase with a classical electromagnetic field, while the other comprises a dense vapour of incoherent, independent molecules. It is now perfectly reasonable that deep inelastic

neutron scattering turns out to be different on water molecules belonging to the different fluids, and that the incoherent fluid scatters the neutrons more strongly than the coherent one (which can transfer quite a lot of momentum to the center of mass, like it happens in the Mössbauer effect): in this way the observed cross sections are given by:

$$\sigma_{H,D} = \sigma_{H,D}^{(i)} \left( \epsilon_{H,D} \frac{N_{H,D}^{(c)}}{N_{H,D}} + \frac{N_{H,D}^{(i)}}{N_{H,D}} \right), \quad (1)$$

where  $N_{H,D}^{(i)}$ ,  $N_{H,D}^{(c)}$  and  $N_{H,D} = N_{H,D}^{(i)} + N_{H,D}^{(c)}$  are the numbers of incoherent, coherent and total  $\text{H}_2\text{O}$  and  $\text{D}_2\text{O}$  molecules respectively,  $\sigma_{H,D}^{(i)}$  the deep-inelastic cross section of the incoherent fluids and  $\epsilon_{H,D} < 1$  the ratio between the coherent and the incoherent cross-section.

Due to the two-fluid nature of both  $\text{H}_2\text{O}$  and  $\text{D}_2\text{O}$ , the fraction  $\xi_{H,D} = \frac{N_{H,D}^{(i)}}{N_{H,D}}$  of incoherent molecules, which in the unmixed liquids at  $T = 300 \text{ K}$  are  $\xi_H \cong \xi_D \cong 0.7$  [4], will in general depend on the molar fraction  $x_D$ , for thermodynamic equilibrium in the incoherent "vapour-like" phase requires:

$$\frac{N_D^{(i)}}{N_D} \rightarrow 1 \quad (x_D \rightarrow 0), \quad (2)$$

$$\frac{N_H^{(i)}}{N_H} \rightarrow 1 \quad (x_D \rightarrow 1), \quad (3)$$

due to the decrease of the chemical potential of the incoherent molecules of the highly diluted species. As a result, calling  $Q^{(0)} = \left(\frac{\sigma_H}{\sigma_D}\right)_{pure}$  the ratio of the cross sections in the pure phases:

$$Q^{(0)} = \frac{\sigma_H^{(i)} [\epsilon_H (1 - \xi_H) + \xi_H]}{\sigma_D^{(i)} [\epsilon_D (1 - \xi_D) + \xi_D]} \quad (4)$$

one obtains the limits:

$$\frac{\sigma_H}{\sigma_D} \rightarrow Q^{(0)} [\epsilon_D (1 - \xi_D) + \xi_D] \quad (x_D \rightarrow 0), \quad (5)$$

$$\frac{\sigma_H}{\sigma_D} \rightarrow Q^{(0)} \frac{1}{[\epsilon_H (1 - \xi_H) + \xi_H]} \quad (x_D \rightarrow 1), \quad (6)$$

which for  $\xi_D \cong \xi_H \cong 0.7$  and  $\epsilon_D \cong 0$ ,  $\epsilon_H \cong 0.5$  gives an adequate representation of the experimental data. A similar analysis, which shall be reported elsewhere [5], gives good account of the other reported anomalies of H<sub>2</sub>O-D<sub>2</sub>O mixtures for Raman scattering [2] and H<sup>+</sup>, D<sup>+</sup> conductances [6].

In conclusion, we would like to emphasize that the surprising anomalies that have been revealed in H<sub>2</sub>O-D<sub>2</sub>O mixtures instead of the problematic (better, untenable) QE appear to give further support to the two-fluid structure of water and to the theory of QED coherence [3] that unambiguously predicts it.

## References

- [1] C.A. Chatzidimitrou-Dreismann, T. Abdul Redah, R.M.F. Streffer, J. Mayers, Phys. Rev. Lett. **79**, 2839 (1997).
- [2] C.A. Chatzidimitrou-Dreismann, U.K. Krieger, A. Möller, M. Stern, Phys. Rev. Lett. **75**, 3008 (1995).
- [3] G. Preparata, *QED Coherence in Matter* (World Scientific, Singapore, 1995).
- [4] R. Arani, I. Bono, E. Del Giudice, G. Preparata, Int. J. Mod. Phys. **B9** 1813 (1995).
- [5] M. Buzzacchi, E. Del Giudice, G. Preparata (in preparation).
- [6] H. Weingärtner, C.A. Chatzidimitrou-Dreismann, Nature **346** 548 (1990).